LA-UR-12-24080
Approved for public release; distribution is unlimited.

Title: Introduction to Mini Muon Tracker

Author(s): Borozdin, Konstantin N.

Intended for: Muon Meeting with TEPCO, 2012-08-13/2012-08-14 (Los Alamos, New Mexico, United States)

Introduction
to
Mini Muon Tracker

Konstantin Borozdin
for
Los Alamos Fuku Team

August 13, 2012

Los Alamos
NATIONAL LABORATORY
EST. 1943

Plan of the Talk

1. 序論 **Introduction**
2. ミューオン **Muon**
3. 追跡者 **Tracker**
4. ミニ **Mini**

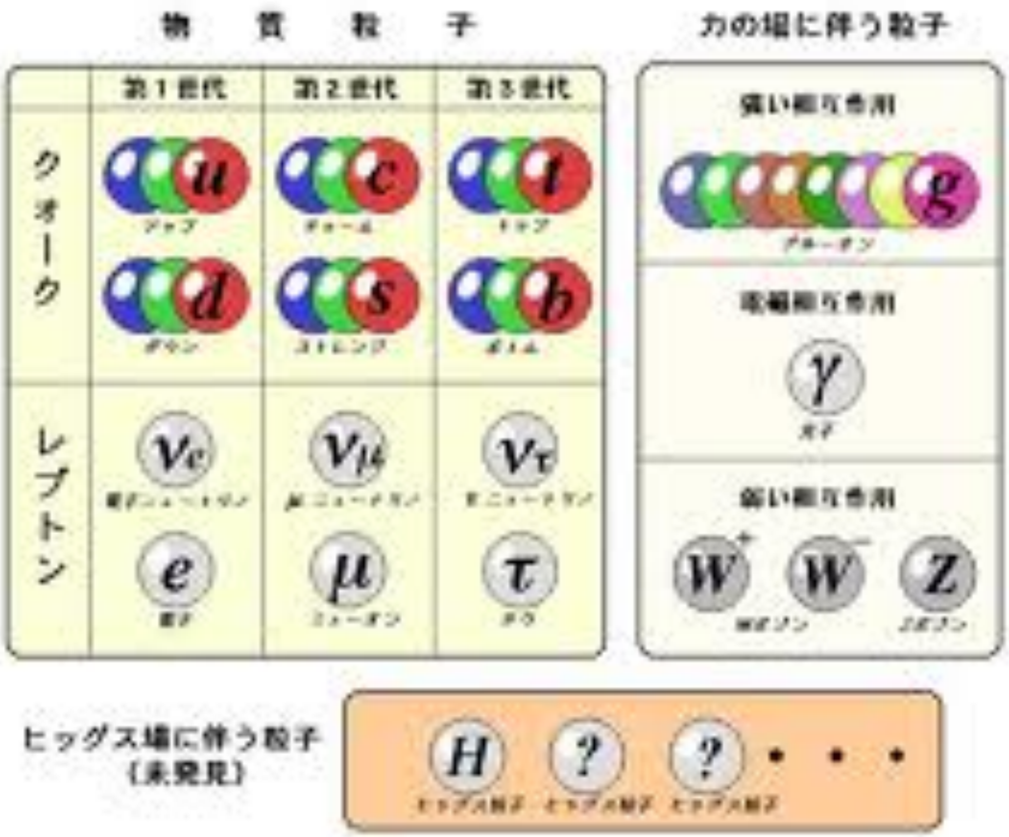
What is Muon?


MUON
μ
muon
The MUON is a short-lived, heavier version of the electron. It has the same negative charge, but is 200 times more massive than the electron.
LIGHT
HEAVY
The PARTICLE ZOO

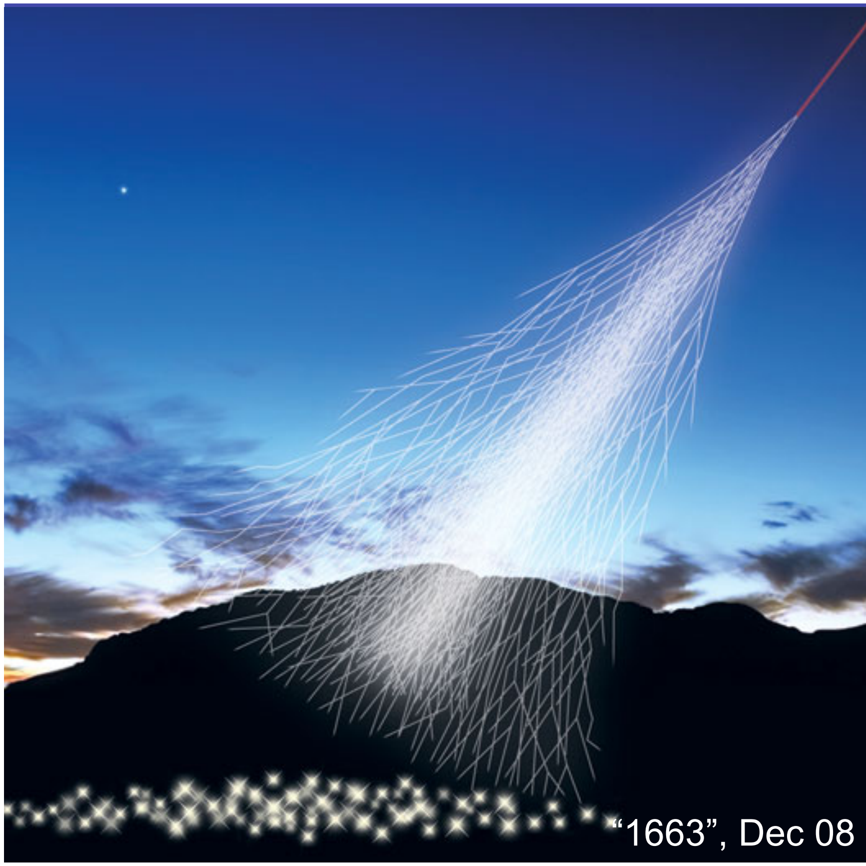
How Muons Look Like?

Los Alamos NATIONAL LABORATORY EST.1943

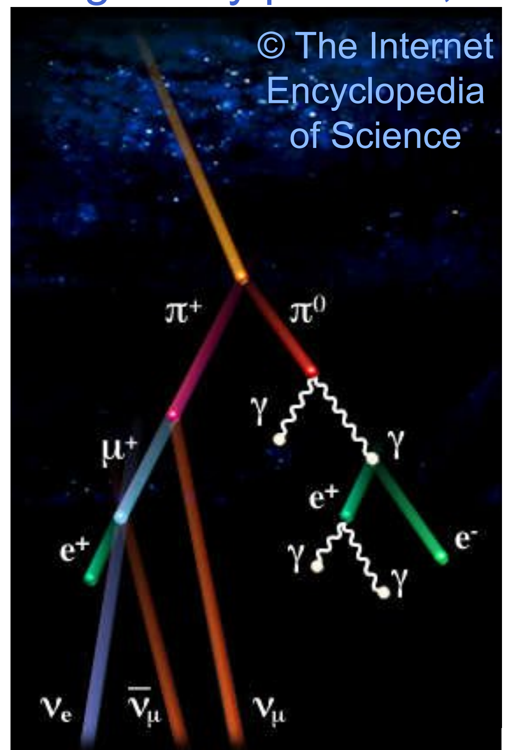
Muons are Leptons



Muon Production in Atmosphere



Mostly protons and α (charged, strongly interacting heavy particles, ~99%)



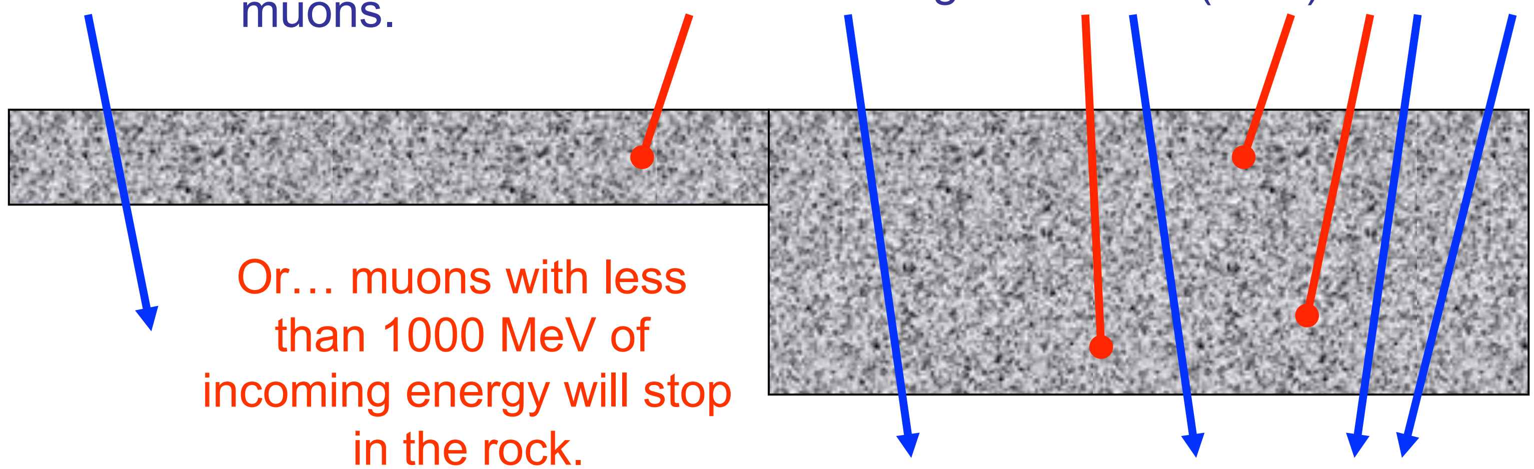
Mostly muons (charged, EM-interacting heavy particles, ~70%) and electrons (charged, EM-interacting, light particles, ~30%). Neutrinos are weakly interacting and can be ignored.

Los Alamos NATIONAL LABORATORY EST.1943

Muons Penetrate Significant Depths

2 meters (6.5 ft) of rock removes about 1000 MeV* of energy from muons.

The average energy of a cosmic ray muon is 3000 MeV and will pass through 6 meters (20 ft) of rock.



Or… muons with less than 1000 MeV of incoming energy will stop in the rock.

Or… half of the cosmic ray muon flux will stop in 6 meters of rock.

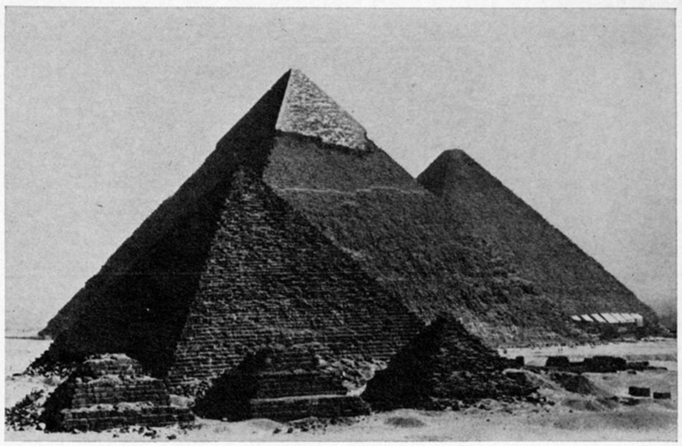
** MeV → Million electron Volts*

Los Alamos
NATIONAL LABORATORY
EST. 1943

Attenuation Radiography with **Muons**

Searching for Hidden Chambers in Pyramids

Fig. 1 (top right). The pyramids at Giza. From left to right, the Third Pyramid of Mycerinus, the Second Pyramid of Che-phren, the Great Pyramid of Cheops. [© National Geographic Society]



Luis Alvarez, et. al.
Science **167**, 832 (1970)

Arturo Menchaca, et. al.
current effort, see

http://www.msnbc.msn.com/id/4540266/

Predicting Volcanic Eruptions

Tanaka, Nagamine, et. al.
Nuclear Instruments and Methods A
507:3, 657 (2003)

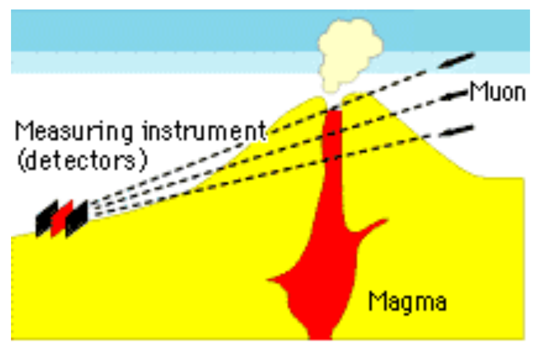
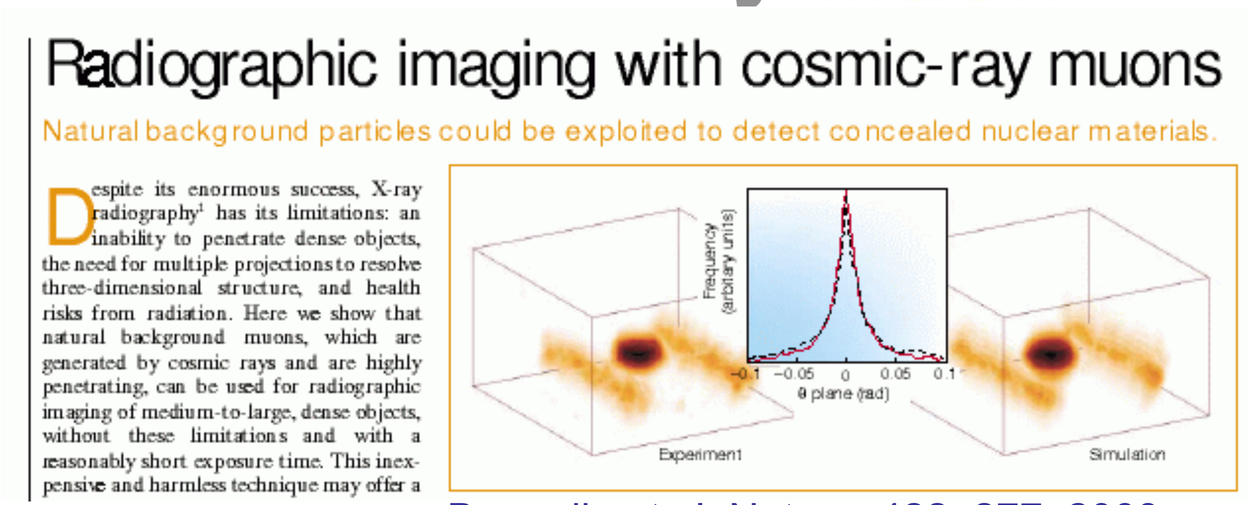


Figure 4: Analyzing the internal structure of a volcanic zone using muons

Los Alamos NATIONAL LABORATORY EST. 1943

Cosmic-Ray **Muon** Tomography

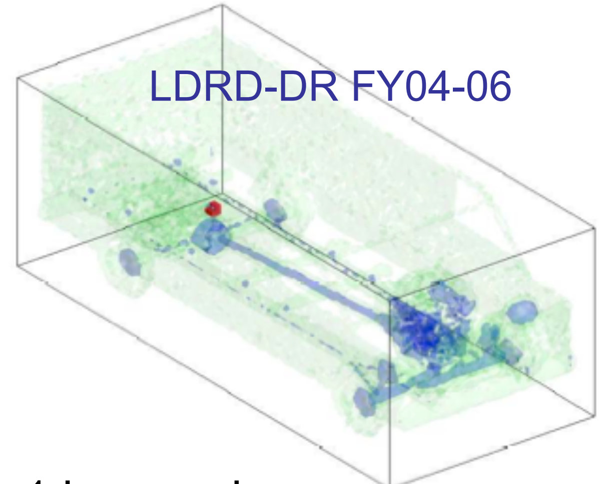


Radiographic imaging with cosmic-ray muons

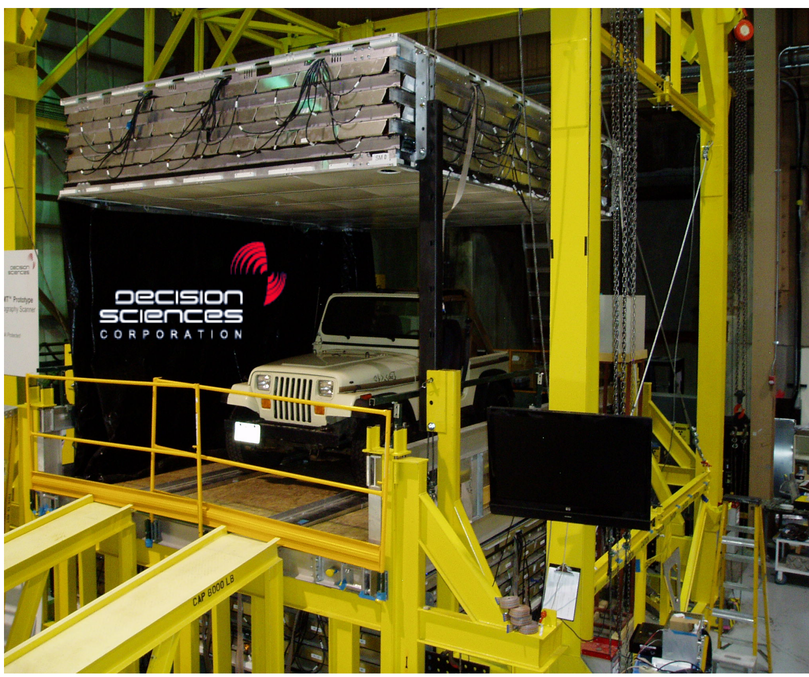
Natural background particles could be exploited to detect concealed nuclear materials.

Despite its enormous success, X-ray radiography[1] has its limitations: an inability to penetrate dense objects, the need for multiple projections to resolve three-dimensional structure, and health risks from radiation. Here we show that natural background muons, which are generated by cosmic rays and are highly penetrating, can be used for radiographic imaging of medium-to-large, dense objects, without these limitations and with a reasonably short exposure time. This inexpensive and harmless technique may offer a

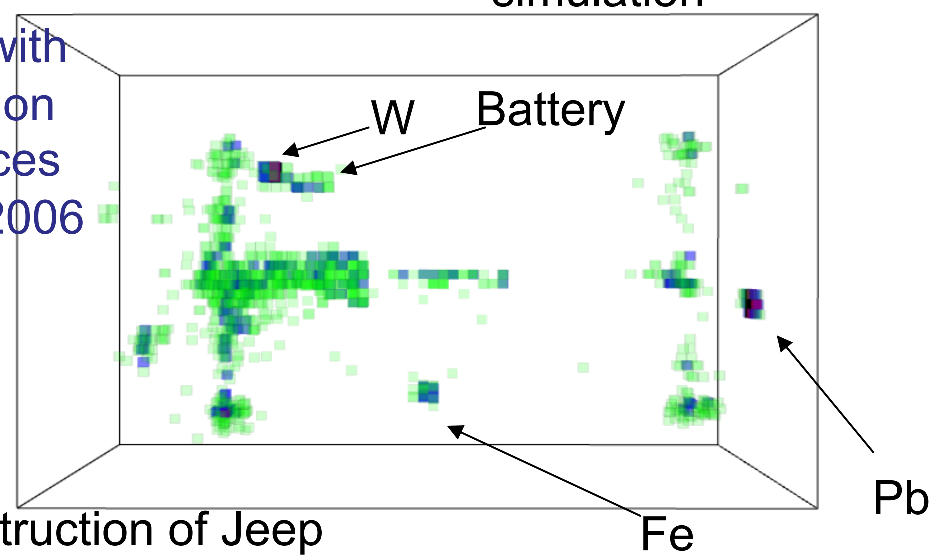
Borozdin et al. Nature, 422, 277, 2003



1 hr cosmic ray exposure simulation

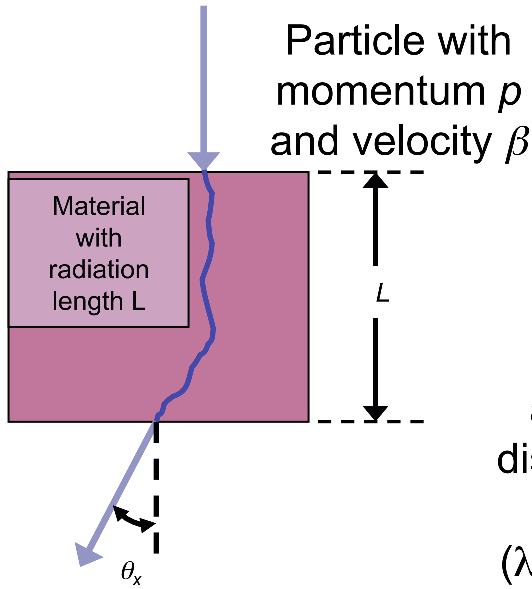


Work with Decision Sciences Since 2006



Reconstruction of Jeep with 3 objects

Scattering Muon Tomography is Based on Particle Tracking



Scattering distribution is approximately Gaussian

$$\frac{dN}{d\theta_x} = \frac{1}{\sqrt{2\pi}\theta_0} e^{-\frac{\theta_x^2}{2\theta_0^2}}$$

and the width of the distribution is related to the material
(λ is a radiation length)

$$\theta_0 = \frac{13.6}{p\beta}\sqrt{\frac{L}{\lambda}}$$

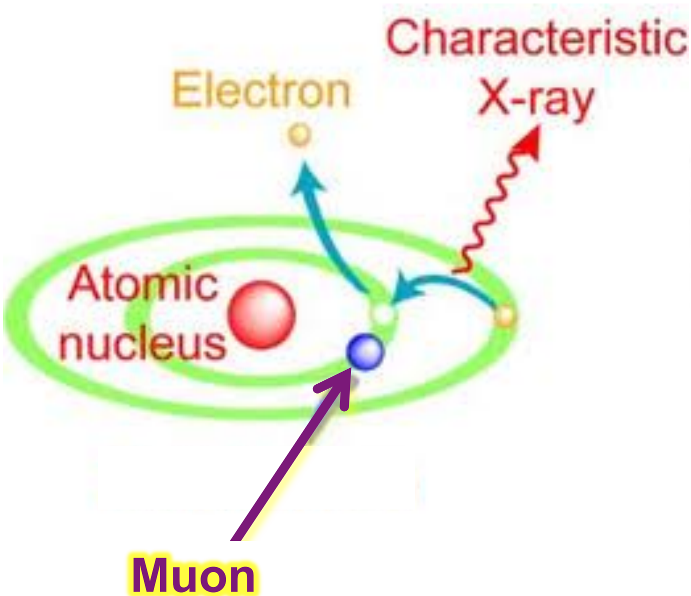
Scattered particles carry information from which material may be identified.

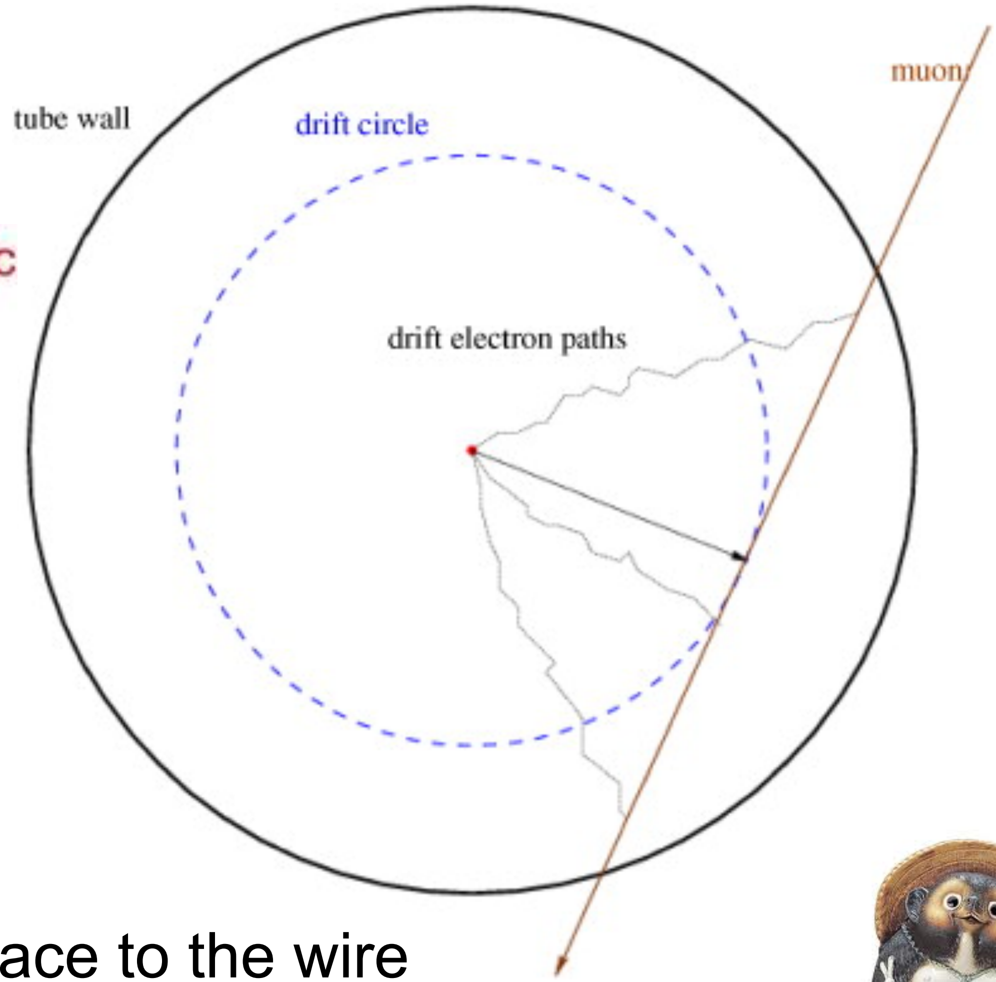
Material	λ, cm	θ_0, mrad*
Water	36	2.3
Iron	1.76	11.1
Lead	.56	20.1
*10 cm of material, 3 Gev muons		

Los Alamos NATIONAL LABORATORY EST. 1943

Drift Tubes: Tracking Charged Particles

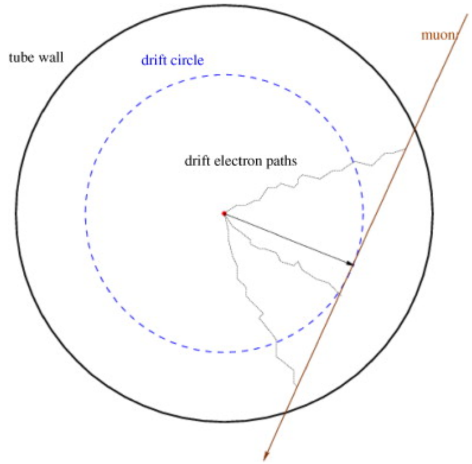
Ionization

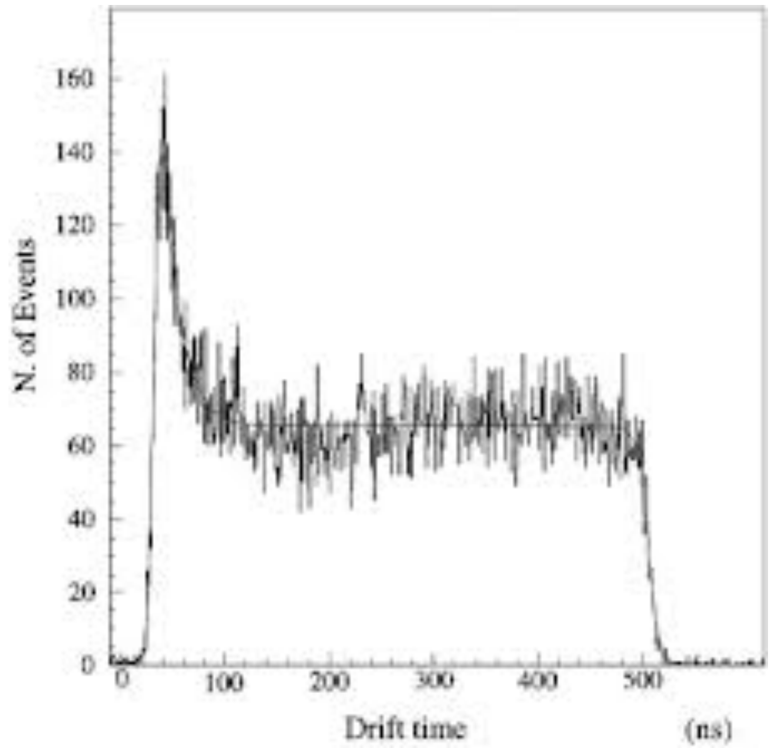




Race to the wire

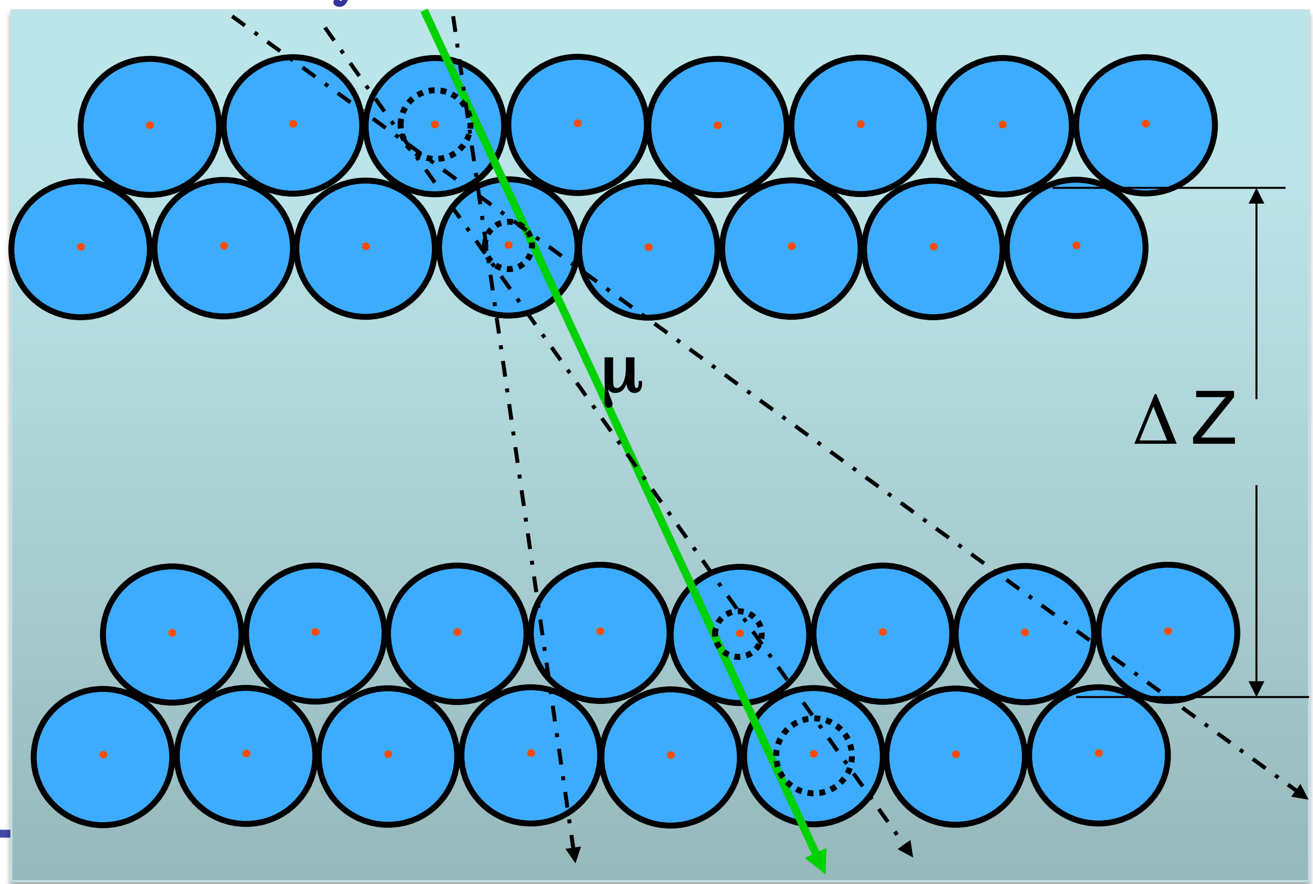
Drift Tubes: Time-to-Radius Conversion





Drift Tubes: Tracking Charged Particles

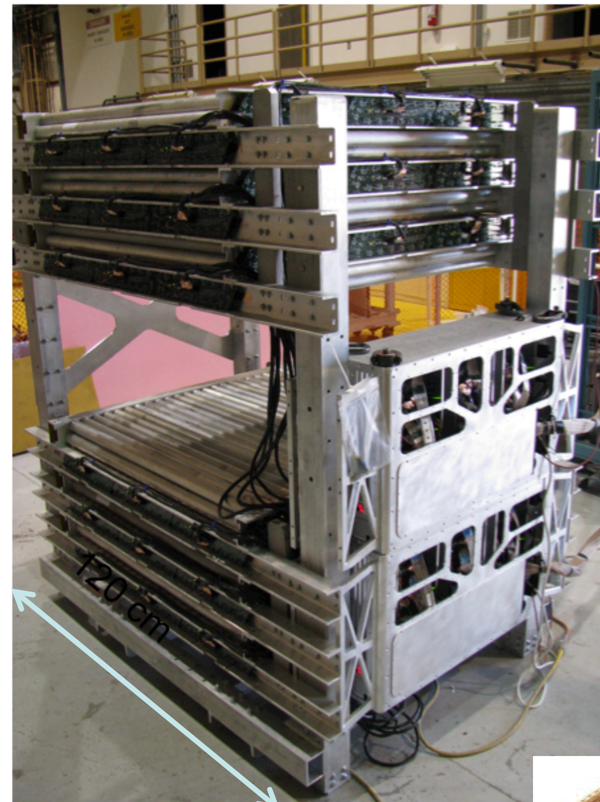
- Cylindrical drift tubes measure radial position of charged particles passing through
- Yields intercept and angle in two dimensions by interleaving tubes having axis oriented in x- and y- directions
- For tomography, banks of tubes are located above and below object to measure scattering angle (average scattering density)



Tracking Charged Particles with MMT

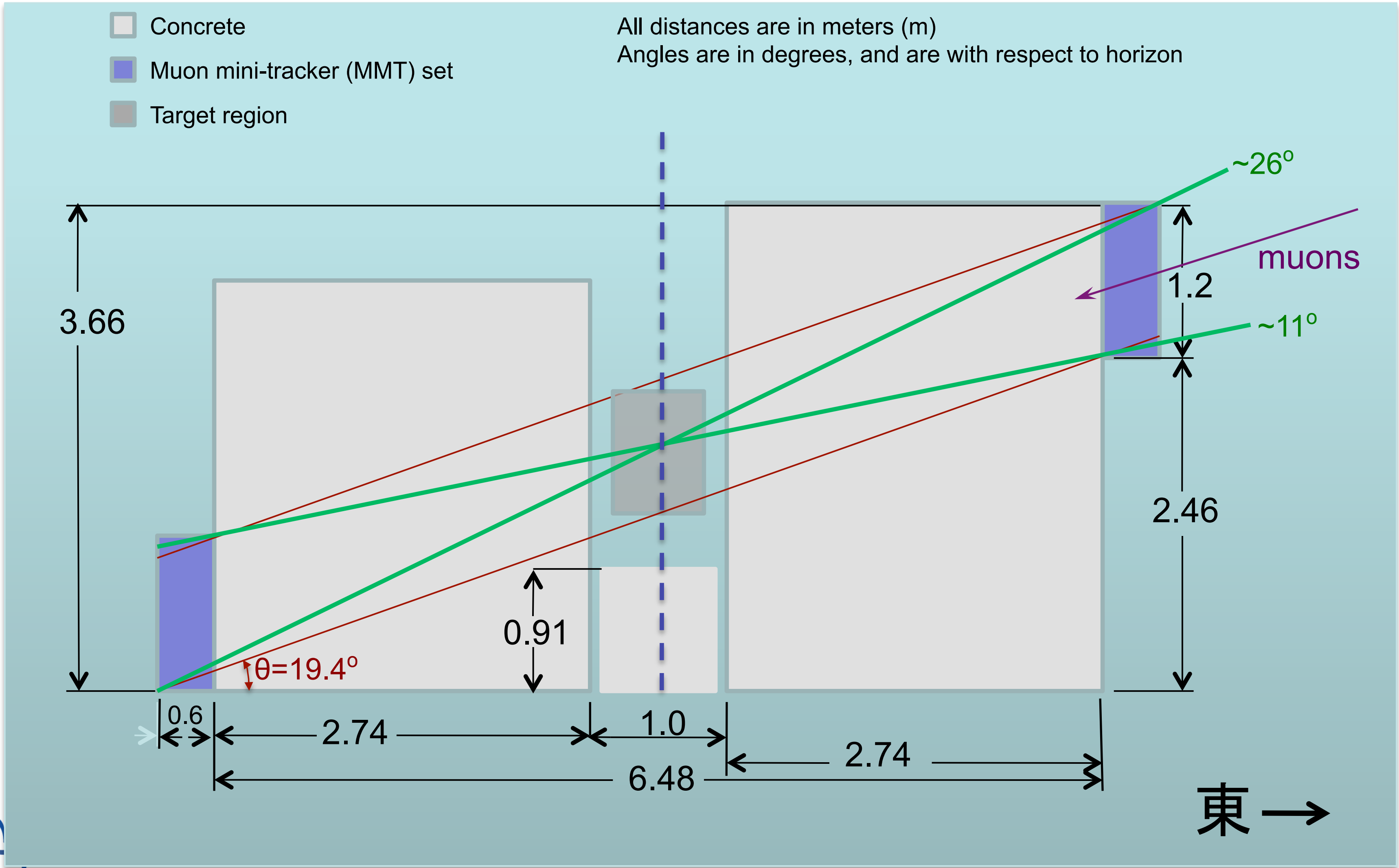
- **576 4-feet long and 2-inch thick aluminum drift tubes**
- **Each tracker set has 3 x-y pairs of double planes, for a 12-fold tracking coincidence, in and out.**
- **Tracker sets moved to “mock reactor”: one set is placed high on shielding, to track incoming muons, the other set is placed low on the “exit” side of the shielding.**

“Out” Tracker

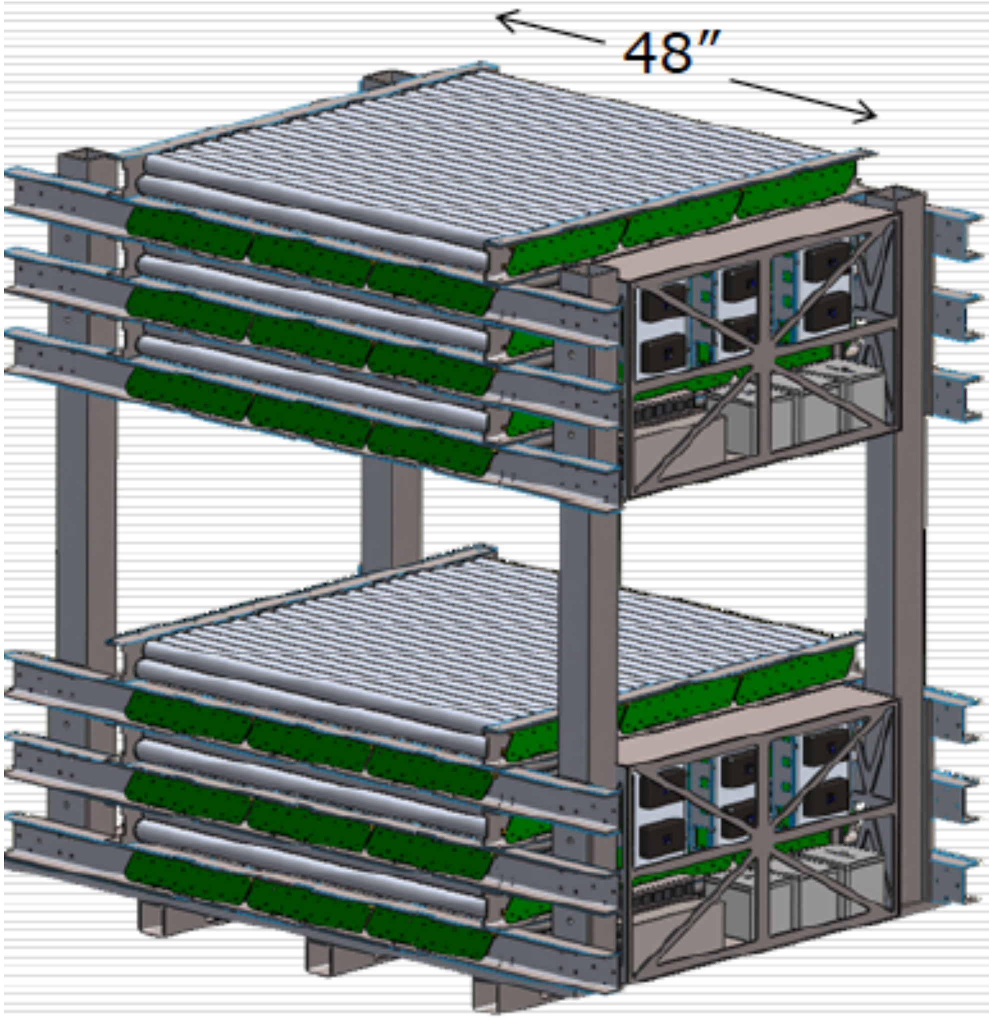


“In” Tracker

Tracking Near-Horizontal Muons



Mini Muon Tracker Design



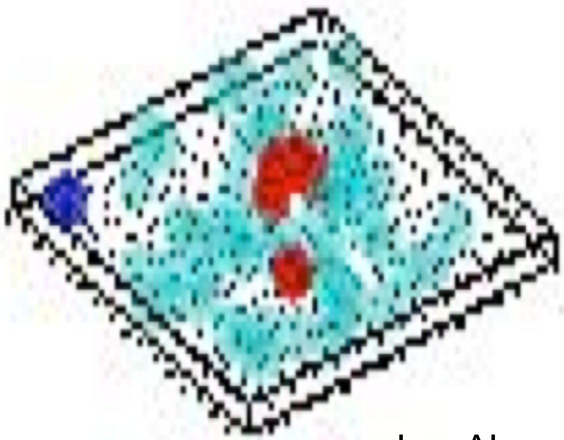
- Supermodules 1,2 are independent units
- Top SM can be repositioned up/down
- Electronics boxes hold:
  - LV, HV supplies
  - Power distribution
  - LVDS/ECL converter boards
- Good grounding & shielding
  - Steel cover strips not shown here
- 48″ C-channel module
- Mobile via forklift or palate jack

Los Alamos NATIONAL LABORATORY EST. 1943

Mini Idea: Have Detector, Will Travel

Using a mini muon tracker developed at the Los Alamos National Laboratory we performed experiments of simple landscapes of various materials, including TNT, 9501, lead, tungsten, aluminium, and water. Most common scenes are four two inches thick step wedges of different dimensions: 12”x12”, 12”x9”, 12”x6”, and 12”x3”; and a one three inches thick hemisphere of lead with spherical hollow, and a similar full lead sphere.

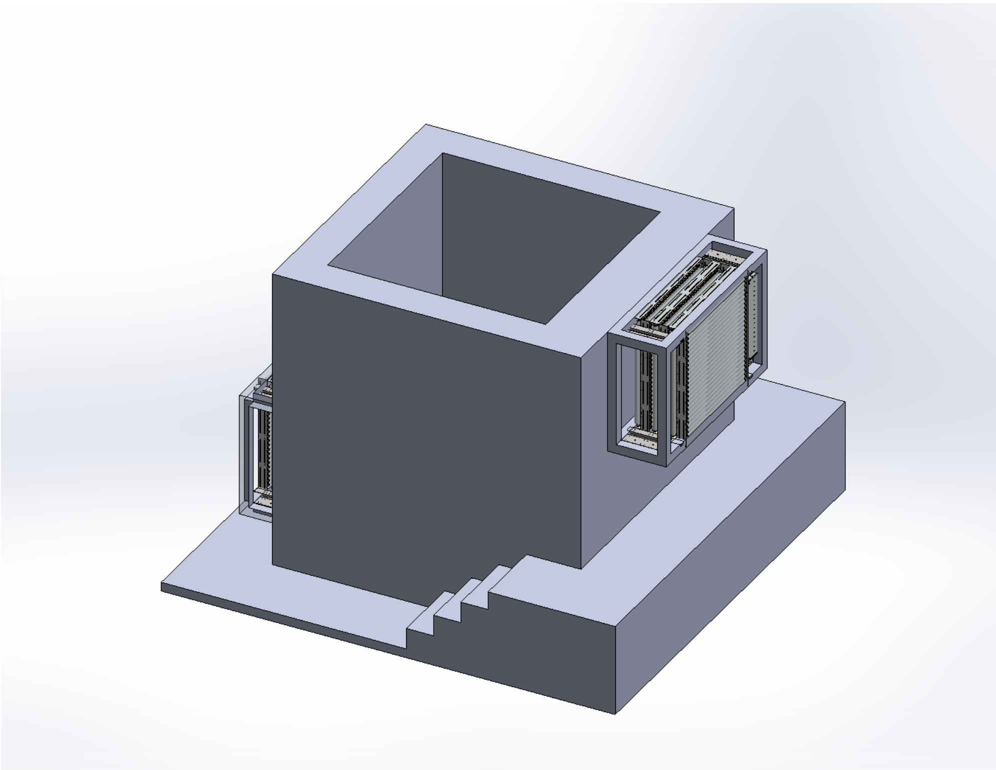
The MMT at the chamber-15 firing site inside its weather-proof shed. The DAQ rack is in the "bunker" building close by.



9501 explosive

Los Alamos NATIONAL LABORATORY EST. 1943

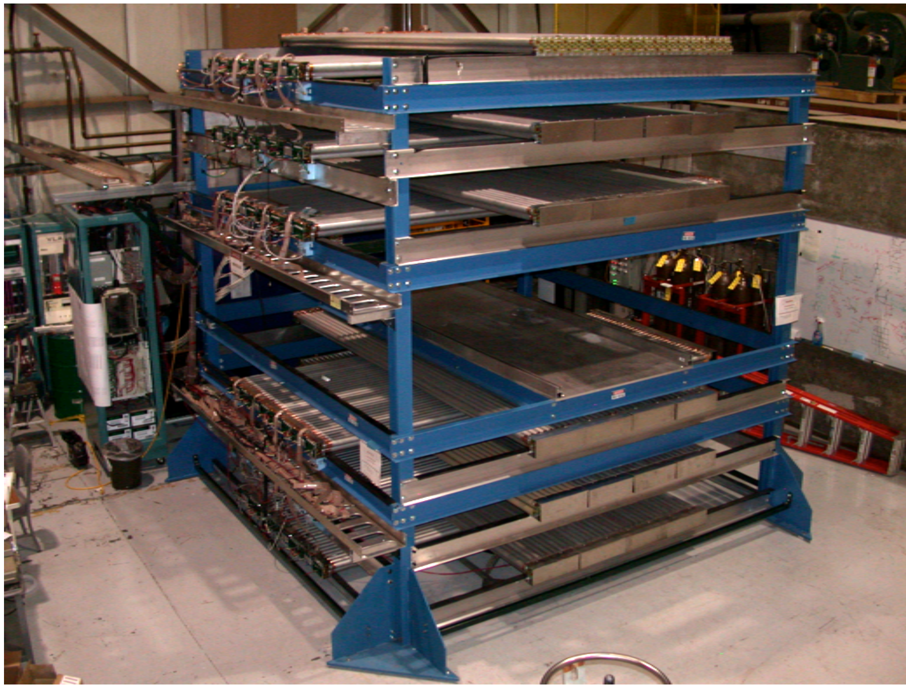
UNM Reactor Imaging with Mini MT



Los Alamos National Laboratory
EST. 1943

Los Alamos NM – Aug 13, 2012

We Have Built Larger Trackers in the Past



We Use Mini Muon Tracker as a testbed
We Will Build Larger Muon Trackers for Fukushima